# PHOTOGRAPHIC METHODS

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EMPLOYED BY THE

# CANADIAN TOPOGRAPHICAL SURVEY

BY

A. O. WHEELER, F.R.G.S.

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# PHOTOGRAPHIC METHODS EMPLOYED BY THE CANADIAN TOPOGRAPHICAL SURVEY

By ARTHUR O. WHEELER, F.R.G.S.,

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**A PAPER READ BEFORE THE EIGHTH INTERNATIONAL GEOGRAPHICAL CONGRESS HELD AT WASHINGTON, D.C., IN SEPTEMBER, 1904.**

## INTRODUCTION.

The writer begs permission to submit to your notice a topographical map of the present tourist portion of the Selkirk Mountains Range of British Columbia, adjacent to the line of the Canadian Pacific Railway, together with a number of enlargements of some of the more striking views used in its construction, and of some views in the adjacent Rocky Mountains Range.

As the map is now in the hands of the engravers, a photographic copy of the original draft can only be submitted. It will, however, serve the purpose of illustration, though somewhat handicapped through lack of distinctive colouring.

The topographical mountain features are shown by contour lines at 100 ft. vertical interval based upon an organized system of control. With the exception of the line of railway, of which a special survey has been made for general purposes of reference through this mountain region, and some minor topographical detail obtained from settlement surveys in the wider valleys, the results have been [illegible]ed entirely from photographic views taken at the several camera stations.

It is not the writer's intention to enter into the scien[illegible] of the application of photography to topographical map representation. Th[illegible] and m[illegible]ably set forth in the works of Col. A. Laussedat, member of the [illegible] France and father of the science, in his three volume book entitled 'Recher[illegible]struments, les méthodes et le dissin topographiques' and other works, by [illegible] in Germany, Italy and Austria, by Mr. E. Deville, Surveyor-General o[illegible] Dominion of Canada in his book, 'Photographic Surveying,' in England by Mr. [illegible]-Lee, by Mr. H. M. Wilson of the United States Geological Survey in his work [illegible]pographical surveying, and by Mr. J. A. Fleamer, of the United States Coast [illegible] Survey in his monograph entitled 'Photographic Methods and Instrum[illegible]

It is now proposed merely to state a few facts in connection with [illegible] presented by the present map and to draw attention to the suitability of [illegible] method to preliminary geographical exploration.

## GENERAL PRINCIPLES OF THE METHOD.

In order to understand the following notes, it is necessary to state briefly the general principles:—

Practically speaking, the photographs are perspectives from which, by the rules of geometry and the inverse problem of perspective, the visible lines or points defining topographical features therein seen may be projected upon a ground plane. It is essential that the features to be mapped be seen in, at least, two views taken from stations some distance apart and of which the position and elevation above a given datum, generally sea level, have been ascertained.

The two stations and the point to be projected should form a fairly well-conditioned triangle, i.e., the line drawn between the stations would be a base subtending an angle of which the point is at the apex, the accuracy with which it is projected depending entirely upon the closeness of the angle to 90°.

A topographical map usually consists of contour lines, which represent the projection on the plan of imaginary lines following the inequalities of the surface at given intervals of altitude.

On the plan, the points are placed in position by projecting thereon the traces of the horizon and principal lines of the two or more views employed, and the lines of sight from each camera station to the said points. The traces of the horizon and principal lines are required for plotting these lines of direction. By inserting needles at the camera stations and using a fine silk thread, or better still a hair from a lady's head, as has been suggested to the writer by a well-known gentleman of the United States Topographical Survey, the work is made mechanical and can be performed through a series of points, very rapidly.

A sufficient number of points along the ridges and dividing water-courses of the area embraced are determined from the photographs to enable an accurate delineation within the scale of the map, to be made on the plan.

The elevation of the points so determined are based upon the elevation of the stations from which the views are taken and are obtained directly from the photographs. The horizontal line of a view corresponds to the altitude of the station. The elevation of any point in the photograph is proportional to its height above or below the horizon line and the distance that its projection falls within or beyond the trace of the horizon line. A scale may readily be constructed to permit of these elevations being taken out rapidly. Elevations should be taken out from all the views employed to fix the position of a point and thus made to check one another. The points thus determined in position and altitude permit contour lines to be drawn at any suitable equi-distance.

The position and relative elevations of the camera stations are ascertained by the ordinary methods of a trigonometric survey, carried to a greater or less degree of refinement. The accuracy and detail of the mapping is dependent upon the precision of the base work, the number of camera stations and the scale of the map. The method is very similar to that of the plane-table, with the following exceptions:—with the plane-table most of the plotting is done in the field, with the camera the same work is done in the office; with the plane-table you can occupy but one station at a time, with the camera, when plotting, you practically occupy both at once. You then have before you, at the same moment, the views taken at the two stations, and thus see the ground simultaneously from both points of view. This is a very strong factor in the identification of points. On the other hand the most perfect photographs are but a weak representation of nature's contrasts, and the delicate inflections of light and shadow are much impaired by transition through the camera lens and reproduction on the best of sensitised plates.

The above are the fundamental principles of the method. There are, however, numerous geometric constructions that assist in obtaining elevations and definition of figures in planes parallel or inclined to the ground plane. For the most part, these require the use of perspective instruments, such as the perspectograph, perspectometer, centrolinead and photograph-board. While materially assisting the delineation and rendering the construction of a map of much greater scientific interest, they can, for the most part, be dispensed with.

The method is applicable to topographical delineation in all classes of country where there is sufficient definition of contours and contrast of features to permit of the identification of points, and may be advantageously used in individual cases, such as rivers flowing through timbered valleys, lakes, irrigation systems, towns, villages, parks, roads, &c., wherever suitable camera stations can be had at sufficient elevation to disclose the details of the area to be mapped. Above all, however, is it suited to the definition of rugged and snow-clad mountainous country, where the season between snow and snow is short, during which time alone peaks can be climbed in safety, and then can only be occupied for an hour or two. In a country of this nature, subject to high winds and sudden fluctuations of climate, the plane table and all ordinary methods of survey are impossible.

## THE FIXIN [illegible] ONS IN POSITION AND ALTITUDE.

It is necessary that son [illegible] n of control should be outlined prior to commencing the photograph work. This may vary from a primary and secondary triangulation of a high degree of accuracy, where the photography is carried on independently from subsequently selected stations, to a mere reconnaissance survey, when, starting from an established base line, the triangulation and photography are carried along together.

To fix camera stations in position four methods may be adopted: (1) If close to a triangulation station, by taking at the station the azimuth from another primary or secondary point, and measuring the distance with a tape; this is the easiest and most accurate method. (2) If distant from a triangulation station, or an independent summit, by erecting a signal, and reading upon it with a transit or theodolite from outside fixed points. (3) By taking one reading upon it from an outside fixed point, and at the station two readings on other fixed points. (4) By taking four or more readings at the station on outside fixed points.

To utilize the third and fourth methods when constructing the map, the readings are plotted on tracing paper and lines drawn in the directions obtained. The pape [illegible] then shifted around until each line passes through the station to which it belo [illegible] The point from which the lines radiate is then at the location of the station to be [illegible] d, and may be pricked through.

This last method may be advantageously used in the absence of an organized system of triangulation, when the survey is of an exploratory nature, and is not carried to a very high degree of accuracy.

## DATUM, SCALE, EQUI-DISTANCE.

Topographical maps are usually referred to sea-level as a datum. In order to ascertain this, the altitude of some point of the survey must be established, either by barometric or trigonometric levelling, or by hypsometrical observations, or, as in the present case, by reference to the levels of a main line of railway carried from ocean to ocean. Any datum, however, can be assumed with reference to some known and definitely fixed point or topographical feature which can subsequently be determined in altitude.

Any scale may be used, and any contour equi-distance from 10 feet up. The larger the scale and the shorter the equi-distance the more laborious the plot and the greater the number of camera stations required, owing to the increase of detail.

For signals along the railway and at stations not far above timber line, a pole ten to twelve feet long, surmounted by a white flag, was set up, and white cotton targets, placed at right angles, used for sighting upon. At long distances above timber line rock cairns, five to seven feet high, were erected. In both cases the signals answered all requirements of the distances at which they were employed.

## MAP OF THE SELKIRK RANGE ADJACENT TO THE CANADIAN PACIFIC RAILWAY.

The map now submitted is on a scale of 1:60,000 in the larger copy, and 1:190,080, or three miles to an inch, in the smaller. It covers an area of 1,100 square miles, and embodies the roughest, wildest and grandest portion of the range. Field work was commenced early in July, 1901, at Albert Canyon Village, a point some twenty-two miles from the Columbia valley at Revelstoke. Signals were set on the surrounding mountains, and at intervals along the railway, and readings and photographic views taken from each respectively, or from suitable camera stations closely adjacent. The work was expanded westward on both sides of the track to the Columbia valley, where a five-mile tangent along the Arrow Lakes Branch of the Canadian Pacific Railway offered a suitable base. About the middle of August it was found necessary to leave the Columbia valley district, owing to the dense smoke from forest fires, and work was taken up at the summit of the range and produced westerly to tie in with that commenced at Albert Canyon. The field work closed at the end of October. The following year, 1902, the survey was expanded northward and southward of the Rogers pass, to cover the tourist portion of the range, commencing at the end of July and terminating at the end of October. Thus the field work extended over a period of seven months, a considerable portion of which was useless owing to dense smoke from bush fires and cloudy and wet weather, the two last being highly detrimental factors in the Selkirks, where a very heavy annual precipitation is the rule.

In 1896 and 1897 an accurate traverse survey had been made of the Canadian Pacific Railway through the mountains, and this survey in conjunction with the construction levels from ocean to ocean, was now used as a base of reference for geographical position and for altitude. The method of trigonometric levels was employed to obtain the latter, and the results shown upon the map are the mean of a series of readings to and from other stations and signals erected at intervals along the line of railway. The distance between camera stations ranges from one to ten miles, but is more generally in the neighbourhood of five miles.

In the field the work was carried on by a party of six:—the writer, two assistants, two packers and a cook. The transport was chiefly by pack ponies and where trails did not exist and ponies could not be taken, on the backs of the party. The instruments are carried to the summits occupied by the climbing party, frequently a work of considerable danger, when treacherous, deeply crevassed snow fields had to be crossed, ice-slopes scaled and beds of snow, ready to avalanche at a moment's notice, to be traversed. To see into deep gorges and obtain working views, overhanging ledges and rock crags had to be occupied, where barely sufficient room could be found to set up the survey instruments, and great care was required in moving around them.

In all, sixty-four ascents were made, with a greatest altitude of 11,113 feet, and a lowest of 1,490 feet above sea level, at the south end of the base. Of these three were over 11,000 feet above sea level, five were over 10,000 feet, nine were over 9,000 feet, while the remainder ranged between 9,000 and 7,000 feet. One hundred and twenty camera stations were occupied, as many as three being placed upon one peak. Seven hundred and sixty-five plates were exposed, and the same number of bromide enlargements made. Of the plates some were duplicates, taken at different exposures for different parts of the view, for the purpose of ascertaining how the photography was going and for other purposes. In almost every case a full circuit was made from each peak, though not necessarily from the same camera station. The time and material expended in taking a few extra views is often of the very greatest benefit, for data missing at some particular station may, in this manner, be found obtainable from another.

### OFFICE WORK.

In the office the work was done by the writer and the two assistants. It comprised the developing of the plates, bromide enlarging from the negatives for plotting prints, the computation and plotting of the control system and camera stations, the taking out of relative elevations, projection on the plan of the points selected for contouring, their elevation above datum, the drawing of the contours, and finally the inking of the completed map. In the original draft the contours are shown in brown, the water-courses, lakes and permanent bodies of ice and snow in blue, the timber in green, roads, trails and townsites in red, and all letter-press and other details in black.

The actual time employed in the above work was fourteen and one half months. The total cost may be summarized as follows :—

Area mapped, 1,113 square miles.

| | |
|---|---|
| Cost of field work | $5,073 74 |
| Cost of office work | 4,395 60 |
| Cost of material | 120 00 |
| Total | $9,589 34 |

Cost per square mile, $8.61.

Cost per acre, 1·34 cents.

### INSTRUMENT.

Of survey cameras and field instruments in connection with photographic surveying, a large number have been invented. The Canadian equipment, designed by Mr. E. Deville, Surveyor-General of Dominion Lands, consists of a plain fixed-focus camera and ordinary transit-theodolite with short, stout, tripod adapted to receive either.

The transit has a three-inch circle reading to minutes, with vertical circle attached to the telescope. The tripod is three feet four inches long and has sliding legs which reduce the length to twenty inches. It packs in the outer case of the transit box. The whole is adjusted by straps for carrying and weighs fifteen pounds.

The camera is an oblong metal box open at one end. It is fitted in an outside wooden case. Cross levels are attached to the metal box in two positions, the longer of which has been dubbed 'the horizontal' and the shorter 'the vertical.' Plates are used. Films have been tried but were found to be insufficiently free from distortion when passing through the developing process. Each plate is carried in a single holder, the outer case of the camera being fitted with a box to contain a dozen. Foot-screws are adapted to the lower side of the camera in either position and permit of its being accurately levelled.

It is absolutely essential that views should be taken on plates in a vertical position. It is, therefore, necessary that the reading of the levels to secure such a position should be obtained before commencing the survey. This is rather a delicate operation and requires some skill. The focal length of the camera is marked on the edge of the metal box against which the plate presses and is registered on every view taken; consequently it appears upon each working print.

The lens is a zeiss anastigmat, No. 3, of series V., the aperture F-18 and the focus 141 millimetres; a deep orange screen is used in front. With a medium speed isochromatic plate, the unit of exposure varies from fifteen to twenty-five seconds.

Plates are 6½ by 4¾ inches and furnish bromide enlargements for plotting purposes of about 10 by 14 inches.

In the horizontal position the lens covers about 56° of an arc, and seven plates are required to complete a circuit, allowing for overlap. In the vertical position the lens covers about 37° of arc and eleven plates are required.

The camera and dozen plates fit together in an outside leather case with straps for carrying and weigh about twenty pounds. The equipment has been found to work well. It is very portable and, owing to the short tripod which is fitted with a canvass bag and can be loaded with rock, is extremely rigid—a most important factor in a class of country where high winds are prevalent. This lack of rigidity would appear sometimes to be a deterring factor in the use of combination instruments and instruments of complicated design. Plates showing the camera and transit-theodolite in use are now submitted, also prints and map showing some of the constructions.

## APPLICATION OF PHOTOGRAPHIC METHODS TO GEOGRAPHIC EXPLORATION.

While photographic methods are undoubtedly suited to the delineation of highly accented topographical areas, over which an accurate system of control has been extended, it would appear to the writer that they are also specially adapted to quick reconnaissance surveys and to geographical exploration. Explorations of this character are frequently carried up the valleys of main waterways, and extended over important lake basins. This is usually accomplished by some form of traverse, using magnetic bearings for direction and rate of travel reckoning for distance, checked by astronomical observations for latitude, and astronomical observations or chronometer reckoning for longitude. Altitudes are generally obtained by means of barometric levels. In such cases, photographic methods can be substituted to great advantage. Both methods start from the same data. By carrying a quick triangulation up a river valley or spreading it over a lake basin, or any other desired area, a more rapid and more accurate result can be obtained; provided, of course, there are points of sufficient altitude bounding or within the area to display it in detail to the camera. It may be put forward that the occupation of each camera station entails an arduous climb. This, however, would furnish no objection to those really in earnest. Two persons only are essential to the camera and transit work, and in most countries porters can readily be had. A strong point in its favour is that the altitude is carried by angles of depression and elevation from point to point, read back and forth between stations, and all others are taken direct from the views. In each view it would be necessary to select a suitable orientation point for direction of the view. This is readily done by reading an azimuth to one of the triangulation stations.

The method can be used either separately or in conjunction with any other, and barometric levels can be carried at the same time as the trigonometric ones. You have, however, the immense advantage of securing for future record a connected series of photographic views, each of which covers an area of the country explored that can be definitely laid down upon a map.

There are three special constructions that would apply in the case of exploration indicated above:—

1. The method of squares is particularly applicable to the delineation of rivers, large and small, flowing through wide bottoms that may be heavily timbered and inaccessible to travel except by the waterway itself. Here, from the surrounding heights of the valley, a bird's-eye view can be obtained, where all the windings and side channels, islands and other details are displayed as on a map. The perspective of a series of squares is now drawn upon the photographic view covering any section of the stream, and a corresponding series of squares drawn in proper position upon the plan. The channels, islands, &c., are then drawn at sight, square by square. It will be readily seen that such a delineation could not be obtained by ordinary methods of traverse at great expenditure of time and money, as it would be impracticable to follow every channel or to delineate every island.

The same construction applies to any particular lake or series of lakes by occupying connected camera stations around their respective basins. The plane-table is generally used for the survey of any special features such as named, entailing a large amount of map construction in the field. By the photographic method the map work can be done entirely in the office upon the explorer's return. It is needless to dwell upon the advantages of this arrangement.

2. A second construction is especially adapted to the configuration of topographical features lying in planes practically parallel to the horizon plane of the camera station, such as lakes, stretches of coast line, swamps with streams winding through them, salt marshes and prairie openings in timbered areas. It is only necessary to know the altitude of the camera station and the altitude of the plane in which the feature lies. With this data the delineation can be made from a single view of such portion as may be covered thereby.

Having selected in the view a sufficient number of points to enable the feature, or various parts thereof, to be sketched, the traces of the horizon and principle lines of the view are laid down on the plan. The points selected are now projected on the trace of the horizon line, and lines drawn to them from the camera station. To the right or left, and parallel to the principal line, a line is drawn at a distance equal to the difference in altitude of the camera station and the plane of the feature to be drawn. The distances of the respective points below the horizon line of the view are now laid off on this line, measuring from the trace of the principal line upon the plan, and lines drawn through the intersections parallel to the said trace. Their intersections with the lines previously drawn from the camera stations to the several projections of the points on the trace of the horizon line establish the relative positions of the points upon the plan, and the bounding lines of the feature to be mapped can be drawn through them at sight.

The same results can be achieved by the method of squares, but it would then be necessary to obtain a new ground plane for each view of the series; whereas, in the present case, once the altitude of the plane parallel to the horizon plane of the camera station is found, it applies throughout the series.

3. Another feature in conjunction with the conduct of an exploration survey by photographic methods appears to the writer to be the facilities it affords to ascertain the altitude of surrounding peaks in mountainous or semi-mountainous country with a considerable degree of accuracy.

While conducting the survey of which the map is now submitted, the writer had occasion to take a series of views from commanding Selkirk points, in which a number of the highest peaks of the adjacent Rocky Mountains range were visible; among others, Mounts Columbia, Bryce, Lyell and Forbes, as best known, were easily identified.

Having plotted the Selkirk triangulation, it was attempted, as a matter of experiment, to compute from the photographs the greatest altitudes of the peaks named. The methods employed were the same as those used in the ordinary reduction of altitudes for points used in contouring :—The position of the peaks were first laid down from the photographs and the distances scaled. The differences in elevation were next computed and a correction applied for curvature and refraction.

In order to ascertain what degree of reliability might be placed upon the computation of altitudes at so great a distance, the altitude of Chancellor Peak—a peak of the main range—was first computed. This altitude had previously been established by the topographical survey from a series of angular readings at 10,780 feet above sea level. It was now computed from four Selkirk views, and the mean result found to be 10,751 feet, with a range of 41 feet, or 29 feet less than that previously established. The distance between the extreme stations of the views employed was a little over 18 miles, and the mean distance to Chancellor Peak forty-five miles. The result seemed to promise altitudes for the four northern peaks that would be a close approximation to the truth.

The Mount Columbia computation, made from views at four different stations, gave a mean altitude of 12,723 feet, with a range of 261 feet.

Mount Bryce was a mean of six stations, and the resultant altitude 11,685 feet, with a range of 235 feet.

Mount Lyell, computed from four stations, showed a mean altitude of 11,459 feet, with a range of 271 feet.

Mount Forbes, from four stations, mean altitude 12,069 feet, with a range of 355 feet.

In each case the extreme distance apart of the computing stations was a little over eighteen miles. The large increase in the range over the Chancellor Peak computation is accounted for by the fact that while the peak named is almost directly opposite the centre of the eighteen-mile base, the lines of sight to the more northerly peaks become oblique, and consequently a greater difficulty is met in plotting their position accurately at so great a distance.

The average distance of Chancellor Peak from the stations occupied is about forty-five miles; Forbes about fifty miles; Lyell about fifty- two miles; Bryce about fifty-eight miles, and Columbia about sixty-two miles.

No instrumental readings were taken upon any of the peaks named, and the results are absolutely from the photographs.

A table has been attached showing the stations from which the computation was made. They appear upon the map now submitted. A second table shows the results of previous computations of the heights of these four peaks obtained from barometric readings. It will be noted how closely they are corroborated by the photographic results, for which it was only necessary to take a few views at distances varying from forty to sixty miles. Among the views exhibited are several used in the above computation.

### TABLE No. 1.

| Peak determined. | Selkirk Station from which determined. | Computed Altitude. | Mean Altitude above Sea Level. | Range. |
|---|---|---|---|---|
| | | Ft. | Ft. | Ft. |
| Mt. Columbia | Mt. Hermit | 12,795 | 12,740 | 261 |
| | Névé | 12,747 | | |
| | Beaver Overlook | 12,839 | | |
| | Mt. Wheeler | 12,578 | | |
| Mt. Bryce | Mt. Hermit | 11,763 | 11,686 | 235 |
| | Mt. Bagheera. | 11,678 | | |
| | Catamount Peak | 11,592 | | |
| | Névé | 11,682 | | |
| | Mt. Wheeler | 11,582 | | |
| | Beaver Overlook | 11,817 | | |
| Mt. Lyell | Mt. Hermit | 11,610 | 11,463 | 271 |
| | Mt. Wheeler | 11,339 | | |
| | Névé | 11,383 | | |
| | Beaver Overlook | 11,520 | | |
| Mt. Forbes | Mt. Hermit | 12,101 | 12,075 | 355 |
| | Névé | 11,989 | | |
| | Mt. Wheeler | 11,928 | | |
| | Beaver Overlook | 12,283 | | |
| The Chancellor | Mt. Wheeler | 10,770 | 10,751 | 44 |
| | Névé | 10,726 | | |
| | Mt. Fox | 10,764 | | |
| | Rogers Peak | 10,755 | | |

### TABLE II.—Comparative Altitudes.

| Peak determined. | Dr. N. J. Collie. | Rev. J. Outram. | A. O. Wheeler from Selkirk Triangulation. |
|---|---|---|---|
| | Ft. | Ft. | Ft. |
| Mt. Columbia | *12,500 | 12,500 | 12,740 |
| Mt. Bryce | *12,000 | 11,800 | 11,686 |
| Mt. Lyell | *11,500 | 11,900 | 11,463 |
| Mt. Forbes | 12,000 | 12,500 | 12,075 |

* Note on Dr. Collie's map "heights marked with asterisk approximate only."

NOTE.—The Selkirk deductions are of special interest in that they closely corroborate previous results obtained from a different base by totally different methods.

A. O. W.